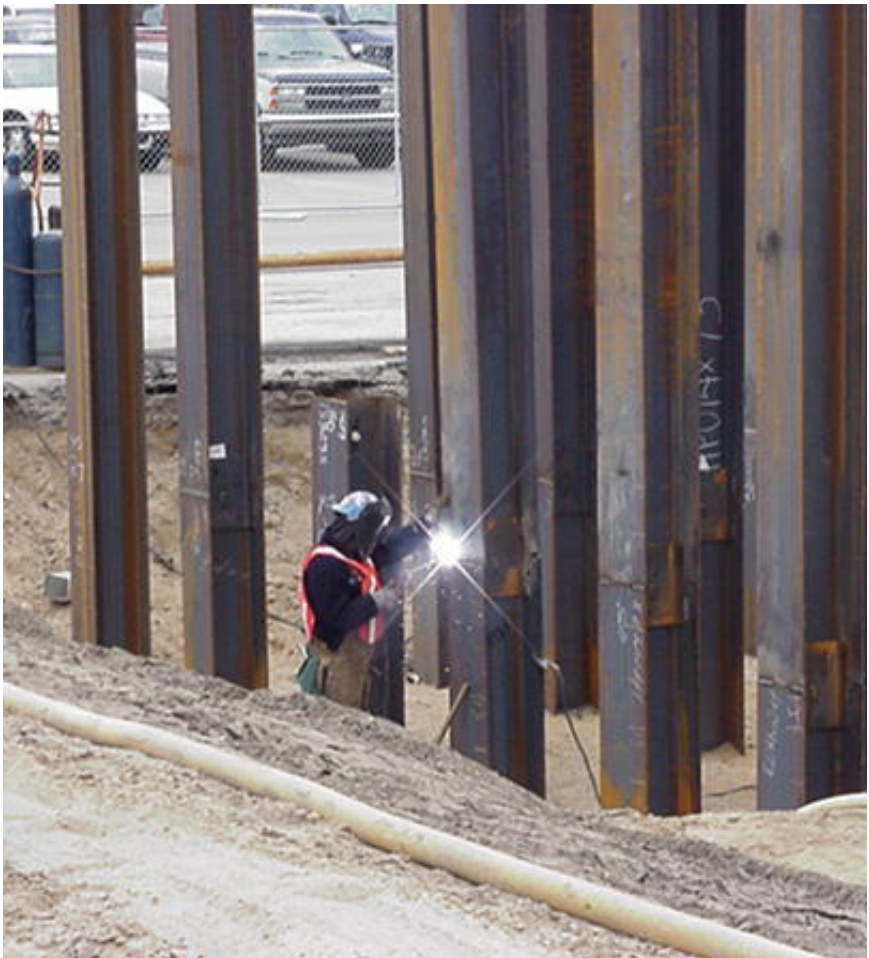


Michigan Department of Transportation

Field Manual for Pile Welding



MDOT Bridge Field Services



1st Edition
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Introduction and Purpose

The purpose of this Field Manual for Pile Welding is to introduce basic welding definitions and concepts, and to provide sufficient understanding of the different types of welds used in splicing piles, in order to assist the inspector in visual inspection and acceptance of pile welds. The Standard Specifications for Construction, Special Provision for Pile Splicing, and American Welding Society (AWS) Structural Welding Code, D1.1 govern field welding of pile splices.

Modern driven pile deep foundation systems support different types of bridges and require piles to resist different types of loads with varying magnitudes. While some piles may only be subjected to axial compression or tension, others may be subjected to bending forces due to thermal, braking, expansion, wind, horizontal earth pressure, and frame/arch action loadings acting on the bridge. Therefore, while some bridges may allow for the use of pile splicing channels, other bridges may require a full penetration groove weld to develop the full bending capacity of the pile section that was modeled during design.

Understanding the bending stresses and cyclic loading that some piles may be subjected to is critical to understanding the importance of a quality welded pile splice. Requiring the weld to survive the stresses induced by the pile driving operation is not the driving force behind the strength requirement of the welded pile splice.

Types of Welds and Processes

WELD TYPES

The MDOT Bridge Design Guides provide the Designer with standard pile welding details utilizing three different weld types:

- *Full penetration groove welds*
- *Partial penetration groove welds*
- *Fillet welds*

A full penetration groove weld is also known as a full penetration butt weld, or complete joint penetration (CJP) weld. When properly designed a CJP weld is stronger than the base metal of the sections it has joined. In order to create a successful full penetration weld, back gouging or a backer bar is used to ensure filler metal from the electrode is deposited throughout the entire cross-section of the weld. CJP welds are used for the H-Pile splice detail and the Pipe Pile detail. Figure 1 shows the cross-section of a full penetration butt weld.

A partial penetration groove weld or partial joint penetration (PJP) weld is similar to a full penetration groove weld with the exception that the base metal sections being joined are only partially penetrated by the weld metal. Since the weld metal is not designed to penetrate through the entire cross-section, the use of a backer bar or back gouging is not required. PJP welds are used for the H-Pile alternate splice detail with channel splicers. Figure 2 shows the cross-section of a partial penetration groove weld.

A fillet weld is used to join sections of base metal lying in different planes and is used for the H-Pile alternate splice detail with channel splicers. Figure 3 shows the cross-section of a fillet weld.

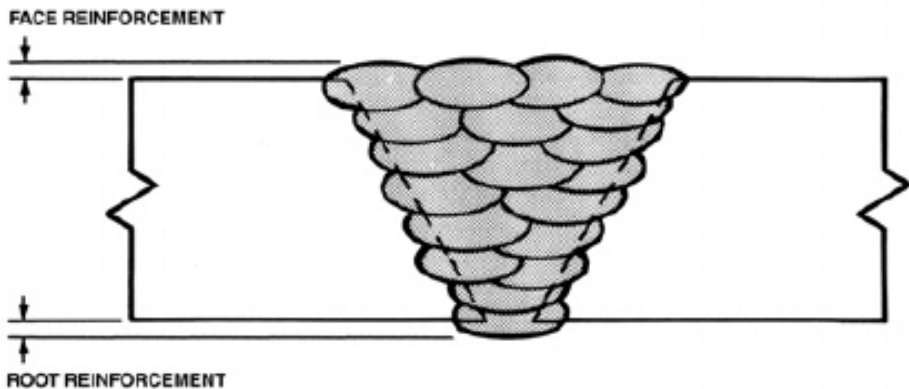


Figure 1. Cross-section of a full penetration groove weld showing individual weld passes.

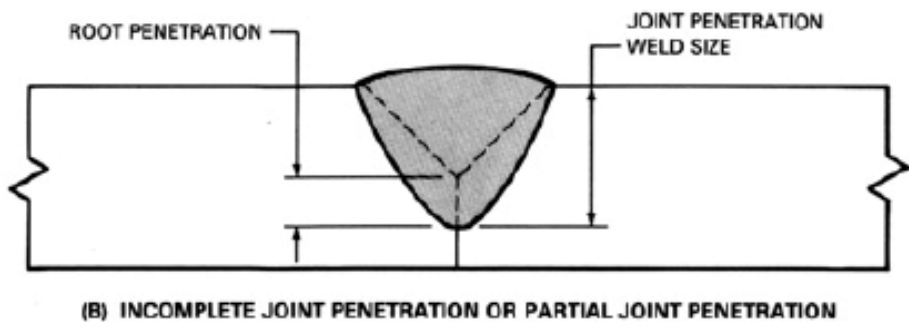


Figure 2. Cross-section of a partial penetration groove weld.

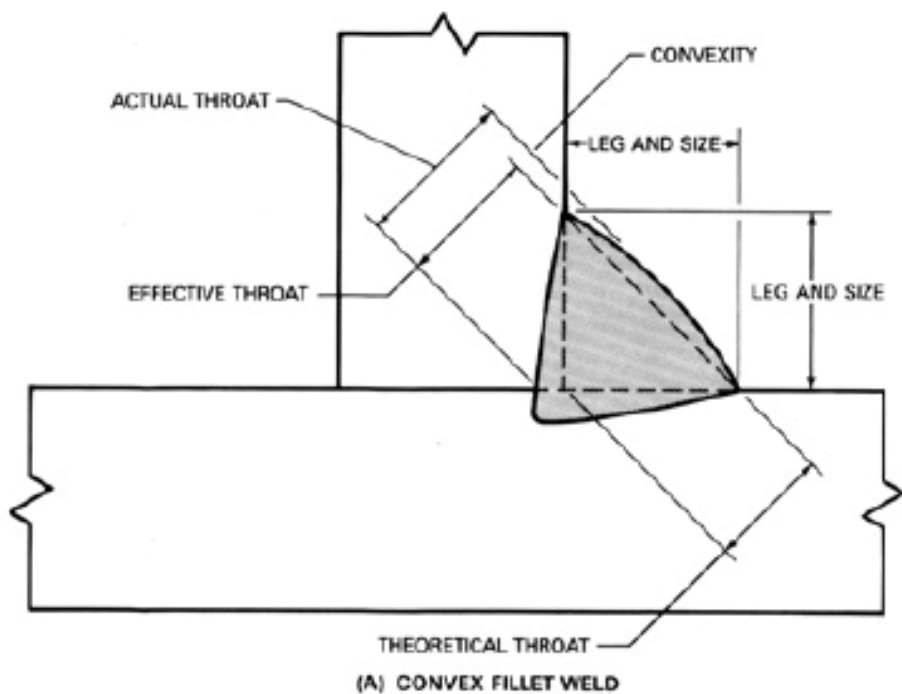


Figure 3. Cross-section of a fillet weld.

WELD PROCESSES

Field welding of piles is limited to the shielded metal arc welding (SMAW) process by the standard specifications, as amended by the Special Provision for Pile Splicing, 12SP705(A). The SMAW process is shown in Figure 4 and is also commonly referred to as stick welding. SMAW electrodes consist of a core of filler metal that is covered with flux, which produces gas and slag to protect the weld from contamination during welding. The slag byproduct, which is deposited on top of the weld metal, must be removed after each weld pass.

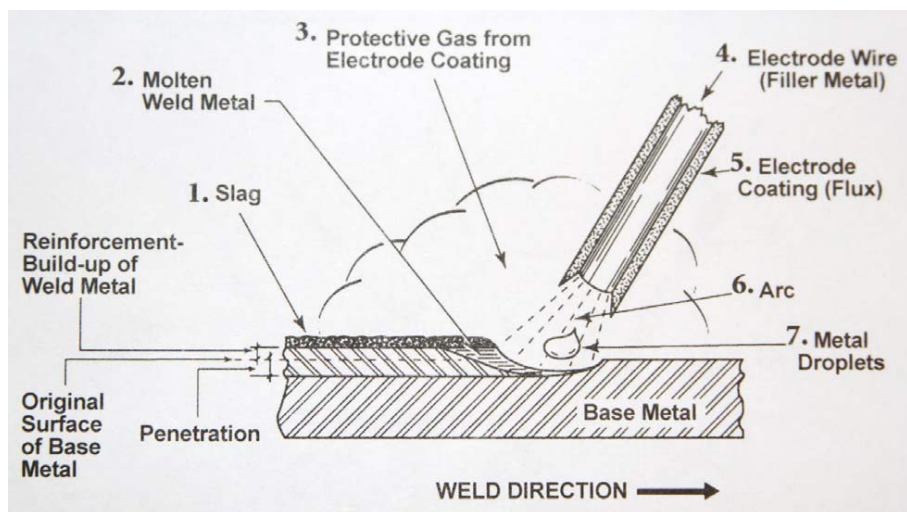


Figure 4. SMAW process.

On rare occasions the flux core arc welding (FCAW) process has been used for field welding. FCAW is a wire fed process that uses flux in the core of the wire in order to shield the weld. FCAW can be used with or without an additional shielding gas. The gas metal arc welding (GMAW) process is also wire fed, but is not suitable for field welding because the gas used to shield the weld can be blown away by wind. The submerged arc welding (SAW) process is typically used in fabrication shops for welding of main structural members. SAW produces a very sound weld and is sometimes used in the field for welding of structural bridge members, but the typical equipment is more suitable for production welding in a shop. Figure 5 below shows a typical SMAW welding machine.



Figure 5. Welding machine.

Definitions of Common Welding Terms

arc strike. Arc strikes are areas where the welding electrode comes into contact with the base metal outside of the final weld. Arc strikes result in heating and very rapid cooling. Arc strikes may result in hardening or fatigue cracking, and serve as potential sites for fracture initiation.

back gouging. The removal of weld metal and base metal from the weld root side of a welded joint to facilitate complete fusion and full joint penetration upon subsequent welding from that side.

backing. A material or device placed against the back side of a joint to support and retain molten weld metal. The material may be partially fused or remain unfused during welding and may be either metal or nonmetal, as approved by the Engineer.

base metal. The metal or alloy that is welded, brazed, soldered, or cut.

bending stress. The stress created in a member subjected to a bending moment. Bending stress results in part of the member cross-section being subjected to tension and part of the member cross-section being subjected to compression, separated by the neutral axis, at which location there is no stress.

CJP. Complete joint penetration.

concavity. The underfill (or suck back) of metal in the weld causing the weld surface to be below flush with the parent metal surfaces. This condition may exist on either root or face surfaces.

convexity. The solidified, overfilled weld metal causing the weld surface to be above flush with the parent metal surfaces. This condition may exist on root or face surfaces and, when measured, both should be added for an accumulated effect.



crater. A depression in the weld face at the termination of a weld bead.

CWI. Certified welding inspector.

defect. A discontinuity or discontinuities that by nature or accumulated effect (for example total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability.

electrode. A device that conducts electricity. In welding, the electrode also can act as the filler metal.


fatigue. Fatigue, as used herein, is defined as the damage that may result in fracture after a sufficient number of stress fluctuations. Stress range is defined as the peak-to-trough magnitude of these fluctuations. In the case of stress reversal, stress range shall be computed as the numerical sum (algebraic difference) of maximum repeated tensile and compressive stresses, or the sum of shearing stresses of opposite direction at a given point, resulting from changing conditions of load.

FCAW (flux cored arc welding). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas.

filler metal. The metal or alloy to be added in making a welded, brazed, or soldered joint.

fillet weld leg. The distance from the joint root to the toe of the fillet weld.

flux. A material used to prevent the formation of, or to dissolve and facilitate the removal of, oxides and other undesirable substances.



fusion. The melting together of filler metal and base metal (substrate), or of base metal only, to produce a weld.

fusion-type discontinuity. Signifies slag inclusion, incomplete fusion, incomplete joint penetration, and similar discontinuities associated with fusion.

fusion zone. The area of base metal melted as determined on the cross section of a weld.

GMAW (gas metal arc welding). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas.

HAZ (heat-affected zone). The portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, or thermal cutting.

hotbox. A storage oven for electrodes. Proper electrode storage requires a hot box to be at a minimum temperature of 250 degrees Fahrenheit at all times.

interpass temperature. In a multi-pass weld, the temperature of the weld area between weld passes.

inclusion. Entrapped foreign solid material, such as slag or oxide.

joint penetration. The distance the weld metal extends from the weld face into a joint, exclusive of weld reinforcement.

joint root. That portion of a joint to be welded where the members approach closest to each other. In cross section, the joint root may be either a point, a line, or an area.

MT. Magnetic particle testing.



NDT. Non-destructive testing.

overlap. The protrusion of weld metal beyond the weld toe or weld root.

peening. The mechanical working of metals using impact blows.

PJP. Partial joint penetration.

porosity. Circular cavity-type discontinuities formed by contamination or loss of shielding gas during solidification of the weld metal.

preheat temperature. The temperature of the base metal in the volume surrounding the point of welding immediately before welding is started. In a multiple-pass weld, it is also the temperature immediately before the second and subsequent passes are started.

PQR (procedure qualification record). A record of welding variables used to produce an acceptable weld and the results of the tests conducted to qualify a weld procedure.

PT. Liquid penetrant testing, also known as dye penetrant testing.

root face. That portion of the groove face within the joint root.

SAW (submerged arc welding). An arc welding process that uses an arc or arcs between a bare metal electrode or electrodes and the weld pool. The arc and molten metal are shielded by a blanket of granular flux on the work pieces. The process is used without pressure and with filler metal from the electrode and sometimes from a supplemental source (welding rod, flux, or, metal granules).

shielding gas. Protective gas used to prevent or reduce atmospheric contamination.



slag. Slag is a byproduct of welding and typically adheres to the weld surface. Slag must be removed between passes and upon weld completion.

SMAW (shielded metal arc welding). An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering and with filler metal from the electrode.

spatter. The metal particles expelled during fusion welding that do not form a part of the weld.

stringer bead. A type of weld bead made without appreciable weaving motion.

tack weld. A weld made to hold parts of a weldment in proper alignment until the final welds are made.

throat of a fillet weld (actual throat). The shortest distance between the weld root and the face of a fillet weld.

throat of a groove weld. A nonstandard term for groove weld size.


travel speed. The rate at which the electrode is moved along the joint during welding, measured in inches per minutes (IPM).

undercut. A groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.

underfill. A depression on the weld face or root surface that extends below the adjacent surface of the base metal. Underfill is the failure of the welder to properly fill the joint with metal.

UT. Ultrasonic testing.

weave bead. A type of weld bead made with transverse oscillation.



weld. A localized coalescence of metals or nonmetals produced by heating the materials to the welding temperature, with or without the application of pressure or by the applications of pressure alone and with or without the use of filler material.

weldability. The capacity of a material to be welded under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service.

weld axis. A line through the length of a weld, perpendicular to and at the geometric center of its cross-section.

weld bead. A weld resulting from a pass. See stringer bead and weave bead.

welder certification. Written certification that a welder has produced welds meeting a prescribed standard of welder performance.


welder performance qualification. The demonstration of a welder's ability to produce welds meeting prescribed standards.

weld face. The exposed surface of a weld on the side from which welding was done.

weld pass. A single progression of welding along a joint. The result of a pass is a weld bead or layer.

weld reinforcement. Weld metal in excess of the quantity required to fill a joint.

weld root. The points, as shown in cross section, at which the root surface intersects the base metal surfaces.



weld size (fillet weld). For equal leg fillet welds, the leg lengths of the largest isosceles right triangle that can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle that can be inscribed within the fillet weld cross section.

weld size (groove weld). The joint penetration of a groove weld.

weld toe. The junction of the weld face and the base metal.

weldment. An assembly whose component parts are joined by welding.

WPS (welding procedure specification). The detailed methods and practices including all joint welding procedures involved in the production of a weldment.

WPS qualification. The demonstration that welds made by a specific procedure can meet prescribed standards.

Acceptance Criteria

The standard MDOT method for acceptance of pile welds is visual inspection. Visual inspection involves inspection before, during, and after welding has been completed, and is performed by MDOT and the Contractor.


SAFETY NOTES:

- *The electric arc gives off ultraviolet and infrared radiation that can cause severe sunburn type injuries which could lead to blindness, therefore: DO NOT WATCH THE ARC!*
- *Both welding and grinding produce sparks. Always wear eye protection around welding and grinding. Keep flammable materials away from the welding area.*

Inspection

Although acceptable to do so, it is not necessarily required to inspect the weld after each pass, but the inspector should periodically visually observe the welding process with sufficient frequency to verify the skills of the welder, joint preparation, preheat, typical root and intermediate passes, back gouging, and visual quality of the final weld passes. The inspector should inspect the first weld done by each welder. After inspecting the first completed welds from each welder, the inspector is required to visually inspect a random quality assurance (QA) sampling of completed welds to verify conformance to the project requirements. Additionally, the inspector should randomly visually inspect the weld setup (immediately prior to welding) as well as intermediate weld passes.

Each welder should also be a visual inspector of his or her own work. The inspector performs QA and the contractor performs quality control (QC), and neither is a substitute for the other. The inspector should verify that the contractor QC personnel are present and



welding is in accordance with the contract documents and the Contractor's Quality Control Plan (QCP). The Special Provision for Quality Control Plan for Welding Foundation Piling Splices will be included in all projects requiring pile foundations. Welders and QC personnel should know when welds display visual discontinuities not acceptable under AWS D1.1. Because each weld pass of every weld is to be inspected by the welder, QC personnel inspects and signs off on every weld, and the inspector (QA) monitors welding in progress and makes a detailed random inspection of completed welds, weld defects or nonconformance to AWS D1.1 should be detected.

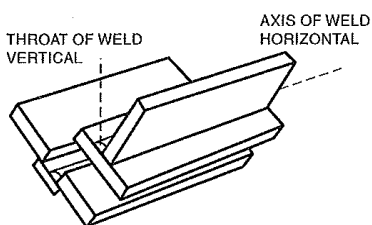
Acceptance

Refer to the QCP, the special provision for Pile Splicing, 12SP705(A), this Manual, and the contract documents when conducting inspection and accepting welds. QC personnel are responsible for inspecting and signing off on all welds, and shall notify the inspector when welds are ready for QA inspection for acceptance. MDOT form 1161L will be used by the inspector to identify which welds were inspected by QA. Form 1161L is used to note which welds were inspected and accepted by QA to verify proper QC; it is not necessary to inspect every weld if welding and QC is present and in accordance with the QCP and the contract documents. A minimum of 10% of the splices should receive QA inspection, though this number can be increased at the inspector's discretion. It is recommended that the splices receiving QA inspection be randomly distributed throughout the duration of the project, while it is also important that each welder have his first weld inspected by QA.

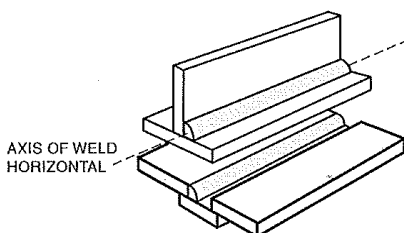
Certification

All welders must be certified in order to weld on MDOT projects, and must carry a copy of their certification. Certifications must be submitted as required in the Special Provision for Pile Splicing, 12SP705(A). The certification will show which positions and welding

type the welder is qualified for. Qualifying in certain positions will permit the welder to weld in other positions. Figures 6 and 7 illustrate the different welding positions, and Table 1 shows which positions tested qualify for which production welding positions. For example, qualifying in the 2F position only qualifies production welding in the flat and horizontal positions for fillet welding, and qualifying in the 3G and 4G positions qualifies production welding in all positions for full penetration groove welding, partial penetration groove welding, and fillet welding.

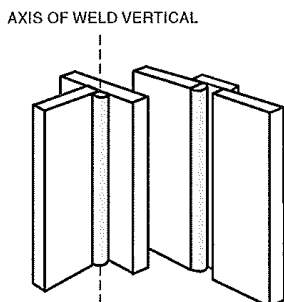


(A) FLAT WELDING TEST POSITION 1F

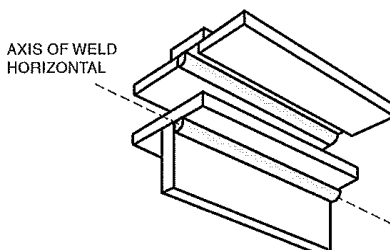


Note: One plate must be horizontal.

(B) HORIZONTAL WELDING TEST POSITION 2F



(C) VERTICAL WELDING TEST POSITION 3F

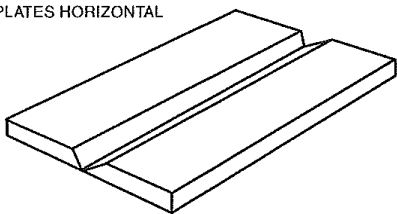


Note: One plate must be horizontal.

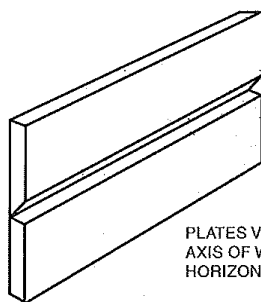
(D) OVERHEAD WELDING TEST POSITION 4F

Figure 6. Positions for fillet welding. (source: AWS)

PLATES HORIZONTAL

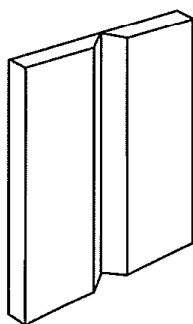


(A) FLAT WELDING TEST POSITION 1G



PLATES VERTICAL;
AXIS OF WELD
HORIZONTAL

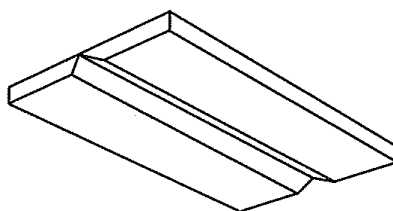
(B) HORIZONTAL WELDING TEST POSITION 2G



PLATES VERTICAL;
AXIS OF WELD
VERTICAL

(C) VERTICAL WELDING TEST POSITION 3G

PLATES HORIZONTAL



(D) OVERHEAD WELDING TEST POSITION 4G

Figure 7. Positions for groove welding (source: AWS)

Qualification Test		Qualified Production Welding		
Weld Type	Positions	Full Pen. Groove	Partial Pen. Groove	Fillet
Groove	1G	F	F	F
	2G	F, H	F, H	F, H
	3G	F, H, V	F, H, V	F, H, V
	4G	F, OH	F, OH	F, OH
	3G + 4G	All	All	All
Fillet	1F	-	-	F
	2F			F, H
	3F			F, H, V
	4F			F, OH
	3F + 4F			All

Table 1. Positions qualified by testing
(F = flat, H = horizontal, V = vertical, OH = overhead).

Note that welding in a vertical downward direction is never permitted, only vertically in the upward direction (starting at the bottom and working towards the top).

Storage

Proper storage and use of electrodes is critical. The standard electrode used for pile welding is E7018, as shown in Figure 8. The first two digits of E7018 designate the minimum tensile strength of the weld metal, the third digit designates the welding position it may be used in (1 = all positions), and the last digit designates the type of electrode coating (8 = low hydrogen). Therefore, an E7018 electrode has a minimum tensile strength of 70 ksi, can be used in all welding positions and has a low hydrogen coating.



Figure 8. E7018 electrodes (typical size is 1/8 inch diameter)

Hydrogen is one of the major causes of weld defects. Care must be taken to ensure no moisture is picked up in the coating of the electrodes as this can add hydrogen to the coating and cause discontinuities in the weld. Electrodes exposed to the atmosphere upon removal from drying or storage ovens (see Figure 9) or hermetically sealed containers (see Figure 10) must be used within two hours, or re-dried at a minimum temperature of 500 degrees Fahrenheit for a minimum of two hours. Electrodes can only be re-dried once, and any electrode that becomes wet cannot be re-dried. Electrodes taken from a hermetically sealed container or drying oven that are not going to be used within two hours should be stored in a portable oven, also known as a “hot box” (see Figure 11), at a minimum temperature of 250 degrees Fahrenheit. The welder should take out only as many electrodes from the hot box as can be used within that two hour period of time.

The following are examples of improper electrode storage:

- *Leaving electrodes out for more than two hours*
- *Open partially used cans of welding rod*
- *Electrodes laying on the ground*
- *Hot boxes with the tops left open*
- *Hot boxes not plugged in overnight*
- *Hot boxes not plugged in during work or generators not running*
- *Hot boxes at a temperature less than 250 degrees Fahrenheit*



Figure 9. Drying and storage oven for electrodes.



Figure 10. Hermetically sealed electrode containers.

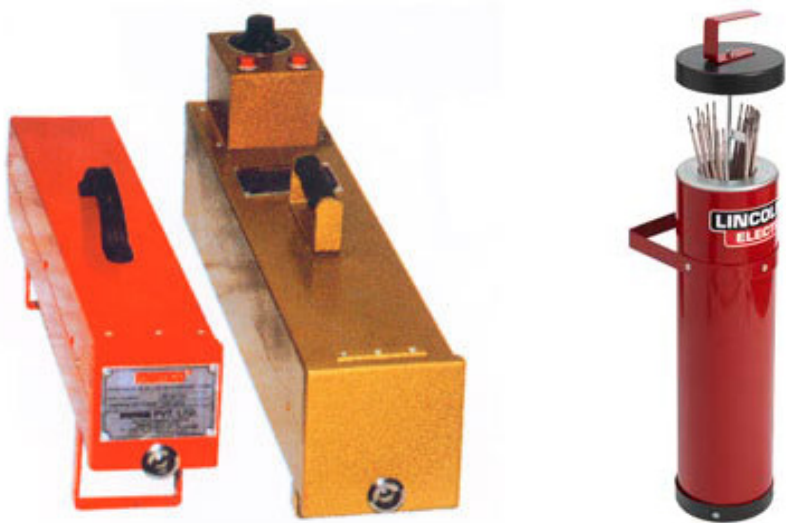


Figure 11. Hot boxes for electrode storage.

Weld Preparation

The first step in making a sound weld is to make sure the joint is correctly cleaned and then preheated (if necessary) prior to welding. Cleaning the joint can be accomplished by using a stiff wire brush. All surfaces to be welded must be free from all loose or thick scale, slag, rust, moisture, grease, or other contaminants. Mill scale that can withstand a vigorous wire brushing, or anti-spatter compound may remain prior to welding.

The pieces to be joined should be checked for flatness, straightness and dimensional accuracy. Likewise, alignment, root opening, fit-up and joint preparation should be examined. Finally, process and procedure variables should be verified, including electrode size and type and equipment settings. These variables should be listed in the weld procedure.

Preheating is the required practice of providing localized heat to the weld zone. The preferred method of preheating is by the use of a manual torch. Preheating to, and maintaining the steel temperature at a minimum of 70 degrees Fahrenheit is required if the ambient temperature is below 32 degrees Fahrenheit. Preheat shall be applied for a distance of 3 inches in all directions from the weld joint. Welding is not permitted when the ambient temperature is below 0 degrees Fahrenheit.

Tack welds or other pieces of steel may be utilized to align the piles before or during welding, but must be removed from the final weld by grinding. Any arc strikes must also be removed by grinding to sound metal.

Welds should be cleaned between every pass and after the final pass. A finished weld should have a clean appearance. Cleaning is typically accomplished by using a stiff wire brush in conjunction with a chipping hammer to remove slag and splatter. The grinder is also a very common and useful tool for cleaning. Grinders are to be used with care to avoid doing more harm than good to both finished welds and the base metal.



Figure 12. Wire brush used to prepare surface prior to welding and to clean between weld passes.



Figure 13. Chipping hammers used to remove slag.



Figure 14. Grinder used to prepare joints, clean before and after weld passes, and to back gouge.

Inspection

Visual inspection of the finished weld is critical. Many weld deficiencies can be detected by proper visual inspection throughout the welding process, which also minimizes the time and cost to make repairs. The finished weld should be checked for both dimensional deficiencies and common weld discontinuities, as shown in the next section.

The only way to check the integrity of a completed CJP weld after the fact, is through a destructive test or NDT. Below are common types of NDT:

- *Dye-penetrant testing*
- *Magnetic particle testing*
- *Radiographic testing*
- *Ultrasonic testing (UT)*

Dye-penetrant testing and magnetic particle testing can identify surface defects and near surface defects, but only radiographic testing or UT can identify all deficiencies throughout a completed weld. These methods are commonly used in fabrication shops for accepting welds. UT can be done in the field if there are concerns about the integrity or quality of the weld. UT may be ordered by the Engineer.

The techniques and issues surrounding weld inspection are broad. If a problem is suspected, consult with Bridge Field Services. It is always better to error on the side of caution. In the next section, some common weld discontinuities are described.

Common Weld Discontinuities

There are many different types of weld discontinuities, which can occur as a result of improper procedures, materials, techniques, or conditions. It is important to remember that a small discontinuity in the weld can become a crack initiation and failure location. However, most discontinuities can be repaired and do not require an entirely new weld. A checklist has been prepared in the next section to assist with visual inspection. If unsure about the severity of a discontinuity, or how it should be repaired, consult with Bridge Field Services. The following are the most common types of weld discontinuities.

Cracks. Any crack is unacceptable regardless of size or location. If a crack is found it must be removed, and NDT may be necessary to verify that all discontinuities have been removed before re-welding. The two types of cracking most likely to occur are hot cracking (just after the weld has solidified) and cold cracking (which occurs near ambient temperature after the weld has cooled).

Craters. Craters are the ends of weld passes where the weld is not filled to its full cross section, typically caused by pulling the electrode away too soon. The stress concentrations that are caused by the unfilled crater may cause crater cracks to form because of tension on the weld in the affected area. All welds must have full cross section the entire length of the weld.

Dimensional discontinuities. Dimensional discontinuities can be found by verifying the weldment against drawings and specifications. Figures 15 and 16 show acceptable and unacceptable weld profiles for fillet welds and CJP groove welds.

Discontinuities may include the following:

- *Misalignment*
- *Incorrect root opening*
- *Warping*
- *Incorrect weld size*
- *Weld profile discrepancies*

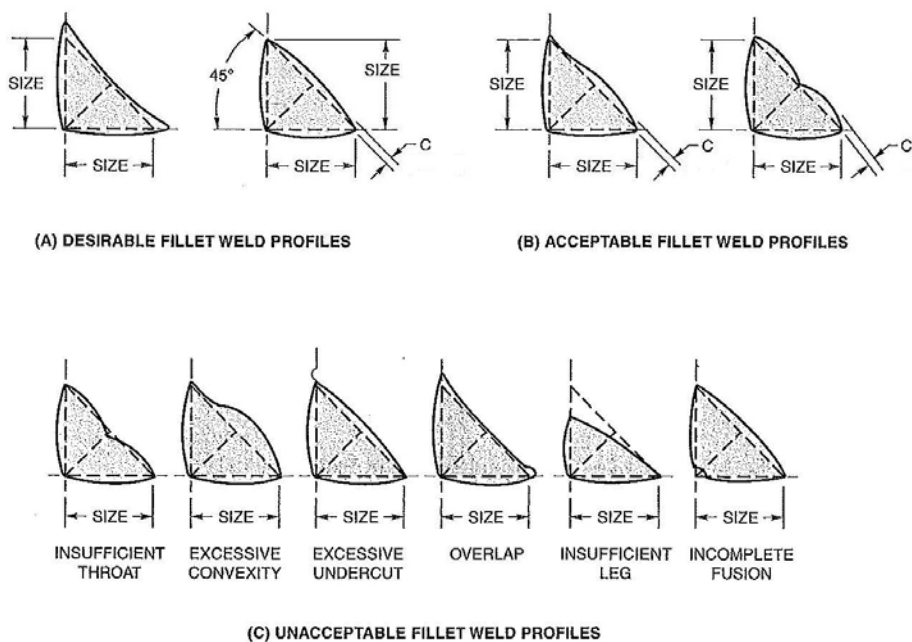
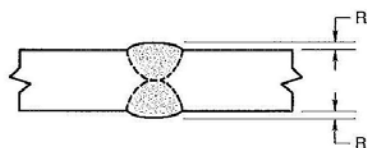
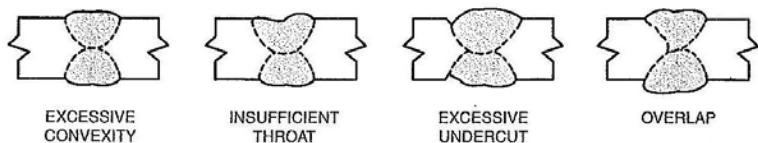


Figure 15. Fillet weld profiles. Source: AWS. (c = convexity)



(D) ACCEPTABLE GROOVE WELD PROFILE



(E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS

Figure 16. CJP groove weld profiles. Source: AWS. (R = reinforcement)

Fillet welds are designed based on their leg sizes. If the plans show a fillet weld size of 5/16 inches then each leg of the weld needs to measure to that dimension. If either leg is under the specified dimension then the strength required for that joint will be less than what the joint was designed for and weld metal must be added. The throat of the weld should also be checked. The leg is in the vertical and horizontal dimensions, and the throat is the distance between the legs, known as the hypotenuse. A fillet weld gauge (see Figure 17) is the standard tool to check fillet weld sizes.

The fillet weld gauge blade must be flush to the base material with the tip touching the vertical member. For convex welds, use the single arc corners for measurement. Place single arc edge flush to base material so blade tip touches vertical member. If the tip touches the vertical member, the weld size is as indicated (see Figure 18a). For concave welds, use the double arc corners for determining if the welds are excessively concave (see Figure 18b). If they are, more filler material is required to build weld throat to the size where the tip between the double arcs touch. Place double arc edge flush to the base material so



tip touches vertical member. If the tip between the double arcs touches the center of the weld, the weld is the profile desired and is the size indicated.



Figure 17. Fillet weld gauges.

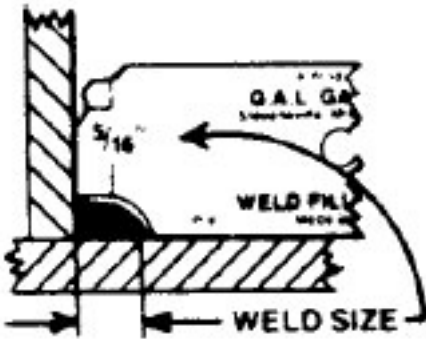


Figure 18a. Fillet weld gauge measuring a convex fillet weld.

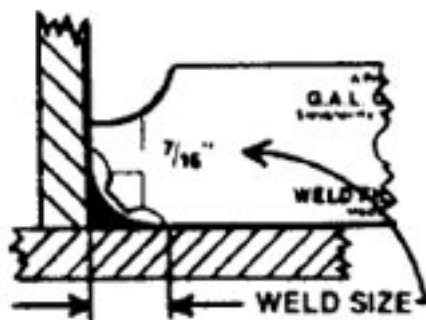



Figure 18b. Fillet weld gauge measuring concave fillet weld.

For convex fillet welds where the width of the weld face is greater than 5/16 inch and less than one inch, the maximum allowable convexity is 1/8 inch. For full penetration butt welds where the thickness of the plates being joined is less than or equal to one inch, the maximum allowable convexity is 1/8 inch. For partial penetration butt welds where the throat size is less than or equal to one inch, the maximum allowable convexity is 1/8 inch.

Dimensional discontinuities can be avoided by proper fit up and by producing a weld of the proper size and profile. Be sure to check the plans and specifications before beginning, and weld size and profile after welding.

When channel splicers are used, a common dimensional discrepancy is a gap between the channel and the pile section(s). If the gap is larger than 1/16 inch, then the fillet weld size must be increased by the amount of the gap to compensate, up to 3/16 inch. Once the gap exceeds 3/16 inch, the weld cannot be accepted.

Incomplete Fusion. Lack of fusion occurs when the base metal fails to melt or mix with the weld material. Surface oxides, such as rust or scale often cause this, as can insufficient welding heat, and improper technique. In some cases, these discontinuities can be identified by a small gap between the fillet and the base metal or along the toe edge.



If no visual discrepancies are observed and if proper material preparation and welding practices are observed, it is generally assumed that complete fusion has occurred.


Incomplete Penetration. A full penetration groove weld is designed to develop the full capacity of the pile section. Incomplete penetration can result from insufficient welding heat or insufficient weld material placement between passes. It is also critical that the full penetration weld be back gouged to sound metal before welding from the backside. Lack of back gouging can trap slag in the weld and result in inadequate penetration at the root of the weld. UT can detect incomplete penetration on a completed weld, but the easiest way to ensure complete penetration is to verify the weld was back gouged to sound metal before completing the weld on the back side, and that the variables of the WPS are being followed.

Overlap. Overlap is a sharp surface connected discontinuity that forms a severe mechanical notch because the weld metal protrudes or flows beyond the toe of face of the weld without fusion. Overlap can occur as a result of improper preparation of the base metal or failure to control the welding process.

Porosity. Porosity is a cavity in the weld that is formed by gas escaping from the molten weld metal during solidification. It is commonly caused by contamination of the base metal or electrode, but can also be caused by improper weld technique, or too fast of a travel speed.

Porosity requirements are as follows:

- *Full penetration butt welds shall have no porosity*
- *For all other groove welds and for fillet welds, the frequency of porosity shall not exceed one in 4 inches of length, and the maximum diameter shall not exceed 3/32 inch*



Undercut. A notch in the base metal along a leg characterizes a weld undercut. Excessive current or improper technique can cause undercut.

Allowable undercuts are as follows:

- *Undercut shall be no more than .01 inches deep when the weld is transverse to tensile stress under any loading condition*
- *Undercut shall be no more than 1/32 inch deep for all other cases*

Underfill. Underfill is a depression on the face of the weld extending below the surface of the adjacent base metal, resulting from the welder not filling the weld joint. Underfill is not acceptable and the finished weld must meet the specified size.

Slag Inclusions. Slag inclusions result from non-metallic solid material being entrapped in the weld metal, between passes, or between weld and base metal. In general, slag inclusions result from faulty welding technique, failure to clean properly between weld passes, failure to back gouge, and conditions that lead to limited access for welding within the joint. Lighter than the weld material, they tend to float to the top of the molten metal. If the slag cannot escape they become trapped in the weld. The welder should pay close attention to properly working the molten puddle to ensure that the slag rises to the top. The risk of slag inclusions can also be reduced by properly preparing the weld surfaces. This may include grinding joint boundaries or between weld passes to ensure no slag is caught in sharp notches or gaps.

Visual Inspection Checklist

All the necessary information to successfully visually inspect pile welds can be found in the plans, standard specifications as amended by special provisions, and this manual.

Before welding:

- ✓ *Ensure welders are certified by MDOT or an approved authorized agency listed in the Bureau of Highways Informational Memorandum (BOHIM) 2003-16 (Appendix C), for the correct position and weld type being used. (The list of authorized agencies is periodically updated and posted on the Bridge Field Services website).*
- ✓ *Verify the weld procedure specifications (WPS) have been approved.*
- ✓ *Check that joint preparation, alignment, root openings, bevels, and fit-up follow approved WPS and contract plans.*
- ✓ *Ensure all weld surfaces are cleaned to remove all coatings, oil, grease, rust, dirt, mill scale, moisture, or other contaminants within the weld zone.*
- ✓ *If the ambient temperature is below 32 degrees Fahrenheit, the pile splice area must be preheated and maintained at 70 degrees Fahrenheit. Welding is not permitted when the ambient temperature is below 0 degrees Fahrenheit. The Engineer may approve heating and housing.*
- ✓ *Ensure contractor quality control is present and in accordance with the contractor's quality control plan.*

During welding:

- ✓ *Verify proper electrode storage, including the following.*
 - *Electrodes to be used in a short time should be removed from a hermetically sealed container or a hot box kept at a minimum of 250 degrees Fahrenheit.*
 - *Any electrodes exposed to the atmosphere for more than two hours must be re-dried for a minimum of two hours at a minimum of 500 degrees Fahrenheit.*
 - *Electrodes not to be used within two hours should be stored in a hot box at a minimum of 250 degrees Fahrenheit.*
 - *Electrodes that have been wet may not be re-dried.*
 - *Electrodes that have been dropped on the ground, exposed to rain, or not stored properly must be discarded, and cannot be used.*
- ✓ *Verify any tack welds used during fit up are ground to sound metal and not included in the final weld.*
- ✓ *Verify the welder is following the approved WPS, following the approved contractor quality control plan, and inspecting his/her own work.*
- ✓ *Verify the welder is cleaning between passes and removing all slag, and repairing any rejectable discontinuities between passes.*
- ✓ *Verify the welder is back gouging to sound metal for full penetration groove welds before welding the backside.*

Final weld inspection:

(Final inspection of the completed weld should not begin before the weld has cooled to ambient temperature)

- ✓ *Verify all slag, spatter, and debris has been removed from the weld surface.*
- ✓ *Verify the weld size, length, and profile meet requirements.*
- ✓ *Verify any arc strikes have been ground smooth, to sound metal.*
- ✓ *Check the final weld for any cracks, porosity, undercut, underfill, overlap, lack of penetration, or lack of fusion.*
- ✓ *Do not accept welds with rejectable discontinuities, these welds must be repaired or replaced. Welds with no rejectable discontinuities shall be accepted and recorded as such on MDOT Form 1161L.*

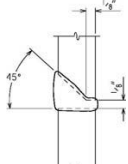
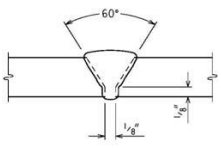
Pre-Approved Welding Procedure Specification (WPS) H-Pile Complete Joint Penetration (CJP)

CONTROL SECTION

Material Specification

Welding process	SMAW
Welding variables	Manual, Multi-Pass, Single Arc
Position of welding	1G, 2G, 3G, 4G
Filler metal specification	E-7018
Welding current	DC
Polarity	Electrode Positive
Welding progression	Flat, Horizontal, Vertical Up, Overhead
Root treatment	See Joint Detail
Preheat temperature	See Special Provision
Interpass temperature	650° F Max

JOB NUMBER

Pass No.	Electrode Size	Welding Current		Travel Speed	Joint Detail
		Amperes	Volts		
All	1/8"	90-160	Volts Will Be Determined by the Amperage Setting on Constant Current Welding Machines	2 - 12 Inches Per Min. (IPM)	<p style="text-align: center;">Back Gouge and Grind Edge Preparation Smooth</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <p>Vertical pile</p> <p>Horizontal pile</p> </div>

Procedure no. MDOT H-Pile CJP-1 Contractor

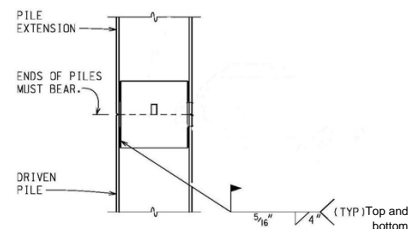
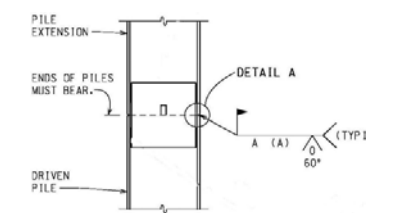
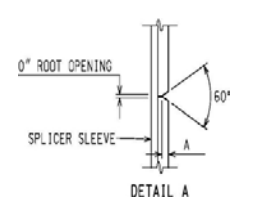
Authorized by Date

- Notes:
- This pre-approved WPS must be completed by the Contractor.
 - The Contractor must supply the Project Engineer with the completed WPS.
 - The welding operator must have the completed WPS in-hand prior to welding.

**Pre-Approved Welding Procedure Specification (WPS)
H-Pile Partial Joint Penetration (PJP)**

CONTROL SECTION		JOB NUMBER		
Material Specification				
Welding process	SMAW			
Welding variables	Manual, Multi/Single Pass, Single Arc			
Position of welding	2G & 3F			
Filler metal specification	E-7018			
Welding current	DC			
Polarity	Electrode Positive			
Welding progression	Horizontal, Vertical Up			
Root treatment	See Joint Detail			
Preheat temperature	See Special Provision			
Interpass temperature	650° F Max			

Pass No.	Electrode Size	Welding Current		Travel Speed
		Amperes	Volts	
All	1/8"	90-160	Volts Will Be Determined by the Amperage Setting on Constant Current Welding Machines	2 - 12 Inches Per Min. (IPM)

Joint Detail

PILE EXTENSION

ENDS OF PILES MUST BEAR.

DRIVEN PILE

5/16" 4 (TYP) Top and bottom

DETAIL A

A (A) 60° (TYP)

0" ROOT OPENING

SPLICER SLEEVE

DETAIL A

Procedure no. <u>MDOT H-Pile PJP-1</u>	Contractor
Authorized by 	Date

- Notes:
- This pre-approved WPS must be completed by the Contractor.
 - The Contractor must supply the Project Engineer with the completed WPS.
 - The welding operator must have the completed WPS in-hand prior to welding.

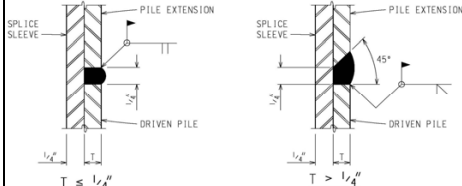
Pre-Approved Welding Procedure Specification (WPS) Pipe Pile Complete Joint Penetration (CJP)

CONTROL SECTION

Material Specification

Welding process	SMAW
Welding variables	Manual, Multi-Pass, Single Arc
Position of welding	2G (Driven Pile)
Filler metal specification	E-7018
Welding current	DC
Polarity	Electrode Positive
Welding progression	Horizontal
Root treatment	See Joint Detail
Preheat temperature	See Special Provision
Interpass temperature	650° F Max

JOB NUMBER

Pass No.	Electrode Size	Welding Current		Travel Speed	Joint Detail
		Amperes	Volts		
All	1/8"	90-160	Volts Will Be Determined by the Amperage Setting on Constant Current Welding Machines	2 - 12 Inches Per Min. (IPM)	 <p>The diagrams show two cross-sections of a pipe pile joint. The left diagram is for a joint with thickness $T \leq 1/4"$, showing a 45° bevel and a 1/4" gap. The right diagram is for a joint with thickness $T > 1/4"$, showing a 45° bevel and a 1/4" gap. Labels include: SPLICE SLEEVE, PILE EXTENSION, DRIVEN PILE, and dimensions $1/4"$ and T.</p>

Procedure no. Pipe Pile CJP-1 Contractor

Authorized by Date

- Notes:
- This pre-approved WPS must be completed by the Contractor.
 - The Contractor must supply the Project Engineer with the completed WPS.
 - The welding operator must have the completed WPS in-hand prior to welding.

Photo Examples – Acceptable



Fillet weld using stringer beads.



Fillet weld using weave bead.



H-pile beveled for a full penetration groove weld.



Good fit up and alignment.



Groove weld showing progression of passes.



Back gouged to sound metal.



Back gouging with a die grinder.



Welding in process.

Note slag to be removed to sound metal by back gouging.



Root pass of a full penetration groove weld free of slag and ready for additional passes.



Additional passes being added to the root pass.



Back gouging to sound metal before welding the back side.



Completed full penetration groove weld. Note that all slag and arc strikes have been removed. Grinding and additional weld metal was added on the flange edges to correct minor misalignment.

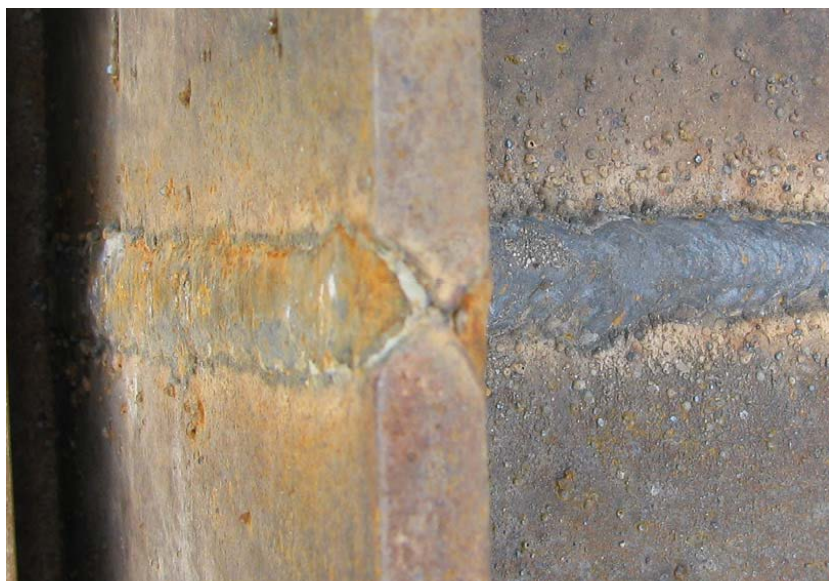
Photo Examples - Unacceptable



Improper root opening, un-prepped surfaces, pile misalignment.



Excessive gap between splicer and pile, incorrect location of fillet welds.



Insufficient back gouging and incomplete penetration.



Porosity.



Misalignment, arc-strikes, unacceptable profile, contaminated surfaces, slag, undercut, porosity, etc.



Misalignment, unacceptable profile, slag.



Slag, undercut, underfill, arc strikes.



Underfill, use of an unapproved wire fed process (GMAW) - note wire protruding from weld.



OFFICE MEMORANDUM

DATE: November 17, 2003

TO: Region Engineers
Region Delivery Engineers
TSC Managers
Resident/Project Engineers
Region Construction Engineers

FROM: Larry E. Tibbits
Chief Operations Officer

John C. Friend
Engineer of Delivery

SUBJECT: Bureau of Highway Instructional Memorandum 2003-16
Welder Certification by Agency (WCBA) Testing

Attached is a current list of agencies that are authorized by the department to run field welder certification tests. Agency test certifications are valid only for pile splicing, temporary sheet piling, false-work welding, permanent metal deck forms, and other temporary non-superstructure bridge or incidental field welding. Structural repairs or rehabilitation welding requires department testing by the Construction and Technology Support Area's Bridge Operations Unit, according to Subsection 707.03.D.8 of the *2003 Standard Specifications for Construction*.

At a minimum, these agencies will supply the test plates, witness the welding, test, and evaluate the completed test coupon. Third party witnessing, testing, evaluation, or issue of certification is strictly prohibited. They have been authorized to issue a welder certification, which will be recognized by the department as noted above. A copy of all passing welder certifications issued by the approved agencies is sent to the Construction and Technology Support Area, Bridge Operations Unit. If a welder's certification is checked by field personnel and the Bridge Operations Unit does not possess a current copy of the certification, the certification shall be considered invalid. Current Michigan Department of Transportation (MDOT) policy is to consider a certification valid for 24 months from date of testing.

Subsection 707.03.D.8.d. of the *2003 Standard Specifications for Construction* also gives the engineer the option of requiring a confirming qualification test during the progress of the work for any welder whose work or qualification is questionable.

Please direct any additional questions you may have concerning the welder certifications or the WCBA Program to Jeff Weiler at 517-322-1235 or Brion Klopff at 517-204-6701 of the Bridge Operations Unit. Our primary objective in allowing agency testing of welders for MDOT is to provide a convenience to contractors. MDOT has no interest in stimulating business or being

influential in competition between testing agencies. The program has proven effective in reducing the cost of welder certification testing to contractors.

Chief Operations Officer

Engineer of Delivery

BOHD:C/T:BK:kab

Index: Welding

Attachment

cc: C & T Support Area Staff
Real Estate Support Area, M. DeLong
Design Support Area, M. VanPortfleet
Maintenance Support Area, C. Roberts
Traffic & Safety Support Area, J. Culp
C & T Support Area, B. O'Brien
OEO - S. El Ahmad
C. Rademacher
V. Blaxton
G. Moore
K. Reincke
T. Fudaly, FHWA
MRBA
MAPA
MCPA
MCA
MAA
AUC
CRAM
MRPA
ACEC
MPA

ALPENA COMMUNITY COLLEGE

665 Johnson Street
Alpena, MI 49707
Phone: 989-356-9021
Fax: 989-358-7554
Contact: Mr. Don McMaster, ext. 7344
Email:
Contact: Scott Mackenzie, ext.
Email:
Contact: Ron Cadarette, ext.
Email:

BAY DENOC COMMUNITY COLLEGE

2001 North Lincoln Road
Escanaba, MI 49829
Phone: 906-786-5802 x 1162
Fax: 906-786-0146
Contact: Mr. Peter Noblet
Email:

DELTA COLLEGE

1961 Delta Road
University Center, MI 48710
Phone: 989-686-9000
Fax: 989-667-2207
Contact: Mr. Bruce Faccio – 989-686-9146
Email:
Contact: Mr. Brian Schultz – 989-686-9471
Email:

DETROIT CARPENTRY

Joint Apprenticeship Training Committee
1401 Farrow Avenue
Ferndale, MI 48820
Phone: 248-541-2740
Fax: 248-541-1660
Contact: Mr. Donald Kissel
Email: don.kissel@detcarpapp.org

FENNVILLE MICHIGAN CARPENTERS

4880 126th Street
Fennville, MI 49408-0670
Phone: 269-561-8115
Fax: 269-561-8125
Contact: Mr. Carles Hicks
Email: carleshicks@msn.com
Contact: Mr. Richard Rose
Email:

FERRIS STATE UNIVERSITY

Welding & Engineering Tech. Dept.
915 Campus Drive, Swan 108
Big Rapids, MI 49307
Phone: 231-591-2639 or 231-591-2952
Fax: 231-591-2407
Contact: Mr. Bill Englund – 231-218-0556 (Cell)
Email:
Contact: Mr. Jeff Carney
Email:

IRONWORKERS LOCAL 8

119 South Front Street
Marquette, MI 49855
Phone: 906-228-6450
Fax: 906-228-3699
Contact: Mr. Gilbert Toslek
Email:
Contact: Mr. Gary Bell
Email:

IRONWORKERS LOCAL 25

50490 West Pontiac Trail
Wixom, MI 48393
Phone: 248-960-2130
Fax: 248-960-0980
Contact: Mr. Michael Relyin
Email: mreylin@ironworkers25.org

IRONWORKERS LOCAL 55

1080 Atlantic Avenue
Toledo, OH 43609
Phone: 419-382-3080
Fax: 419-382-3085
Contact: Paul Pirrone – 567-686-6063
Email: paul@iw55.org

IRONWORKERS LOCAL 340

510 East Columbia Avenue
Battle Creek, MI 49014
Phone: 269-962-8511
Fax: 269-962-1485
Contact: Mr. Ken Dumas
Email: local340ironworker@sbcglobal.net

KALAMAZOO VALLEY COMMUNITY COLLEGE

6767 West O Avenue
Kalamazoo, MI 49003-4070
Phone: 269-488-4263
Fax: 269-488-4458
Contact: Mr. Erick Martin
Email:

KELLOGG COMMUNITY COLLEGE

Regional Manufacturing Technology Center
405 Hill Brady Road
Battle Creek, MI 49015-5613
Phone: 269-965-3931 x 2832
Fax: 269-962-7370
Contact: Doug Adams
Email:

LANSING COMMUNITY COLLEGE

4100W – Manufacturing
Engineering Tech. Dept.
P.O. Box 40010
Lansing, MI 48901-7210
Phone: 517-483-9682 (Bill)
Phone: 517-483-1359 (Cathie)
Fax: 517-483-1320
Contact: Mr. Bill Eggleston
Email: egglesb@email.lcc.edu
Contact: Ms. Cathie Lindquist
Email: lindquc@email.lcc.edu

MACOMB COMMUNITY COLLEGE

South Campus
14500 12 Mile Road
Warren, MI 48903
Phone: 586-445-7459
Fax: 586-445-7130
Contact: Mr. John Kacir
Email:

MATERIALS TESTING CONSULTANTS

693 Plymouth Avenue
Grand Rapids, MI 49503
Phone: 616-456-5469
Fax: 616-456-5784
Contact: Doug Hula
Email:
Contact: Aaron Zimmerman
Email:

MERRILL FABRICATORS

520 Republic Avenue
Alma, MI 48801
Phone: 989-293-2359
Fax:
Contact: Steve Chapman
Email: schapman@merrillfab.com

METAL MENDERS

9931 Lucerne
Redford Township, MI 48239
Phone: 313-937-2453
Fax:
Contact: Lawrence Battis – 586-764-4999 (Cell)
Email:

MICHIGAN CARPENTERS APPRENTICESHIP

1221 Division Street
Marquette, MI 49855
Phone: 906-225-9088
Fax: 906-225-1160
Contact: Mr. Robert Soper
Email:

MID-MICHIGAN COMMUNITY COLLEGE

1375 South Clare Avenue
Harrison, MI 48625
Phone: 989-386-6622 x 680
Fax: 989-386-2411
Contact: Mr. Don Graham
Email:
Contact: Mr. Mark Jewel
Email: mjewel@midmich.edu

MILLWRIGHTS 1102 APPRENTICESHIP

27555 Mound Road
Warren, MI 48902
Phone: 586-573-4660
Fax: 586-573-2468
Contact: Mr. David Poletis
Email: dpoletis@millwrights1102.org

MONROE COMMUNITY COLLEGE

1555 South Rasinville Road
Monroe, MI 48161-9746
Phone: 734-384-4118
Fax: 734-384-4243
Contact: Mr. Andrew Burke
Email: aburke@monroeccc.edu
Contact: Mrs. Valentina Burke

N.T.H. CONSULTANTS, LTD.

38955 Hills Tech Drive
Farmington Hills, MI 48831-3432
Phone: 248-553-6300
Fax: 248-489-0727
Contact: Mr. Joe Jackson
Email:
Contact: Mr. Robert Good – 248-640-0835 (Cell)
Email:

NON-DESTRUCTIVE TESTING GROUP

8181 Broadmoor SE
Grand Rapids, MI 49316
Phone: 616-891-3570
Fax: 616-891-3565
Contact: Mr. Joe Kucharski
Email:
Contact: Mr. Bob Bills
Email:

NORTHERN MICHIGAN UNIVERSITY

D.J. Jacobetti Center, Room 140B
1401 Presque Isle Avenue
Marquette, MI 49855-5396
Phone: 906-227-1532 or 906-227-2073
Fax: 906-227-1549
Contact: Mr. Carl Peterson
Email:
Contact: Mr. David Staples
Email:

O.T.C.

9543 Susin Lane
Clarkston, MI 48348
Phone: 313-310-2874
Fax: 248-620-9511
Contact: Mr. Jerome Steward
Email:

S.M.E

The Kramer Building
43980 Plymouth Oaks Boulevard
Plymouth, MI 48170-2584
Phone: 734-454-0629
Fax: 734-454-0629
Contact: Mr. Michael Gase
Email:

SOILS & STRUCTURES

6480 Grand Haven Road
Muskegon, MI 49441
Phone: 800-933-3959
Fax: 231-798-1383
Contact: Bryan Mulcahy – 231-206-1060 (Cell)
Email: bmulcahy@soilsandstructures.com

SPEC-WELD TECHNOLOGIES

Phone: 419-898-6874
Contact: Terry E. Lowe
Email: specweldtech@amplex.net

TESTING ENGINEERS AND CONSULTANTS

1343 Rochester Road
Troy, MI 48099-0249
Phone: 248-588-6200
Fax: 248-588-6232
Contact: Mr. Tony Morris
Email:
Contact: Mr. Marty Williams
Email:

TRAVERSE BAY AREA CAREER-TECH. CENTER

880 Parsons Road
Traverse City, MI 49684
Phone: 231-922-6291 or 231-922-6276
Fax: 231-922-6364
Contact: Mr. Charles Hunt
Email:

WASHTENAW COMMUNITY COLLEGE

4800 East Huron River Drive, EOB
P.O. Box D-1
Ann Arbor, MI 48106
Phone: 734-973-3627
Fax: 734-677-5078
Contact: Mr. Coley McLean
Email:
Contact: Mr. Clyde Hall
Email:

WEST SHORE COMMUNITY COLLEGE

3000 North Stiles Road
Scottville, MI 49454-0277
Phone: 231-845-6211 x 3235
Fax: 231-845-7227
Contact: Mr. David Cutler
Email:

Attach pile layout sketch showing footing outline and numbering of piles. Identify test piles

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Construction Field Services– Geotechnical Services Section, Bridge Design - Lansing

[illegible]

*QA verification shall be performed on a minimum of 10% of the piles. See the MDOT Field Manual for Pile Welding for more details.